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The Role of Health Information Systems in Improving Medication Safety During Anesthesia

Ahmed Ibrahim Ahmed Alasiri[1], Hatim Yahya Ahmed Alfaifi[2], Khalid Ali Mohammed Asiri[3], Saleh Saeed Hadi Alabatahin[4], Adel Hamad Ali Shuqayfi[5], Othman Ibrahim Yahya Gasem[6], Mohammed Hadi Ali Abu Shamla Kuriry[7], Rashed Mahdi H Alyami[8]

[1]Specialist-Anesthesia Technology, Najran Armed Forces Hospital, Ministry of Defense Health Services, Najran, Saudi Arabia

[2]Specialist-Anesthesia Technology, Najran Armed Forces Hospital, Ministry of Defense Health Services, Najran, Saudi Arabia

[3]Specialist-Anesthesia Technology, Najran Armed Forces Hospital, Ministry of Defense Health Services, Najran, Saudi Arabia

[4]Pharmacy Technician, Najran Armed Forces Hospital, Ministry of Defense Health Services, Najran, Saudi Arabia

[5]Technician-Pharmacy, Armed forces hospital in jazan, Ministry of Defense Health Services, jazan, Saudi Arabia

[6]Technician-Pharmacy, Armed forces hospital in jazan, Ministry of Defense Health Services, jazan, Saudi Arabia

[7]Technician-Pharmacy, Armed forces hospital in jazan, Ministry of Defense Health Services, jazan, Saudi Arabia

[8]Technician-Anesthesia Technology, Najran Armed Forces Hospital, Ministry of Defense Health Services, Najran, Saudi Arabia

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ABSTRACT

Introduction: Patient safety in anesthesia has been threatened by medication errors that are severe as the administration of strong medications often occurs immediately and there is no time to recover after the mistake. Sixty-nine percent of anesthesia clinicians in Saudi Arabia report having committed at least one drug error throughout their career with the key issues cited being haste, heavy workload, and poor communication. The Kingdom is actively embracing Health Information Systems (HIS) in an attempt to curb these risks and standardise perioperative care under the Saudi Vision 2030 framework.

Study Objective: By conducting this systematic review, we will have a comprehensive understanding of how Health Information Systems (HIS) are currently utilized in the Kingdom of Saudi Arabia, including Electronic Health Record (EHR), Anesthesia Information Management System (AIMS) to improve the safety of drugs administered in anaesthesia.

Methodology: The review examined peer-reviewed clinical research data, institutional cohort data of large tertiary centers such asKing Faisal Specialist Hospital and Research Center (KFSHRC) and national policy papers of the Saudi Food and Drug Authority (SFDA) and the Saudi Patient Safety Center (SPSC). The analysis concentrated on the quantitative measures, including the rate of documentation completion, the rate of error interception, and the satisfaction of users.

Conclusion: HIS has shown a strong potential of decreasing human error and enhancing the quality of perioperative data in Saudi Arabia. Nevertheless, the maximum levels of their safety require human factor consideration, e.g., burnout, optimization of user interfaces to avoid alert fatigue, and non-punitive culture of reporting, instead of observing the fear of errors and teaching it to the organization.

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Keywords: *Health Information Systems, Anesthesia Information Management Systems, Clinical Decision Support, Medication Safety, Anaesthesia, Operating Room*

1. INTRODUCTION

Background

The perioperative environment is highly complicated and requires an intricate infrastructure in keeping the environment safe especially in relation to the use of strong pharmacological agents during anesthesia. The healthcare sector in the Kingdom of

Saudi Arabia is experiencing a transformation never witnessed before through the umbrella of Saudi Vision 2030 and the

Health Sector Transformation Program that focus on the adoption of sophisticated Health Information Systems (HIS) to reduce medical errors and improve the quality of care. Medication errors (MEs) are a burning issue on the global level, and in the high-priority environment of the operating theater, there is virtually no room for error. [6], [7] The shift of old manual techniques to digital ones, such as Anesthesia Information Management Systems (AIMS), Computerized Physician Order Entry (CPOE), and Clinical Decision Support Systems (CDSS), is an intentional attempt to establish systemic protection against avoidable injury. [11]

Medication error and Safety

Medication errors are also a major issue on concern among the healthcare givers and policymakers in Saudi Arabian hospitals. The studies show that pharmaceutical errors in Saudi hospitals are between 13 and 56 per 100 medication orders. **[2], [5]** These errors are made during different phases of medication use process; prescription, dispensing, administration and monitoring. In the wider hospital setting, the most common cases of errors in prescribing are recorded, which make up about 52.70 percent of reported errors. **[7]** Nonetheless, in the anesthesia unit, administration errors acquire an even greater significance because intravenous drugs directly affect the physiology of patients and have an immediate effect. **[9]**

The particularity of medication errors in the anesthesia environment is that in most cases, the drugs of high alertness include opioids, neuromuscular blocking agents, and vasoactive medications. A survey of clinicians in the field of anesthesia in Saudi Arabia found that 69 percent of the participants had committed at least one anesthetic drug error in their professional lives. Although most of these errors involve a type of near-miss that did not lead to any harm, about 10.2 percent of clinicians reported drug errors that related to adverse events, such as cardiac arrest or irreversible neurological damage. **[6], [13], [7]** The etiology of such errors is complex, and often, they are caused by organizational weaknesses, but not personal laxity.

Anesthesia Information Management Systems

Anesthesia Information Management Systems (AIMS) are a paradigm of changes in the way perioperative data is gathered and used. AIMS are computerized systems, which import automatically real-time vital signs, which is in place of the traditional hand written records. The technology enables the anesthesiologists to be more vigilant since they have less cognitive load when it comes to manual documentation. **[11], [3]** The use of AIMS has been researched in the most prominent institutions in Saudi Arabia such as King Faisal Specialist Hospital and Research Center (KFSHRC). A comparison study of handwritten records versus Electronic Anesthesia Records (AER) established that the electronic form was much higher in terms of completion of information (62.3% vs. 48.0%). **[4]** Such quality improvement in documentation is important to patient management, clinical research and quality assurance, and legal protection.

Although it has advantages in the completeness of documentation, the shift to AIMS presents new complications. Indicatively, the KFSHRC study established the average time of handwritten report was 45.9 minutes as opposed to 53.9 minutes of an electronic record, implying that the online process might not be as efficient in the time-saving aspect. **[7], [12], [8]** Nevertheless, nearly three-quarters of the unit (79 percent) of the respondents in a survey on satisfaction assumed that the Bedside Medical Device Interface (BMDI) of the system contributed to capturing parameters automatically; therefore, the unit saved time by not entering them manually in the long-term.**[9]**

Decision Support Mechanisms

Computerized Provider Order Entry (CPOE) systems are that which are meant to eliminate the mistakes via illegible handwriting and transcription of medication orders with the help of electronic entries. CPOE in combination with Clinical Decision Support Systems (CDSS) gives real-time alerts about drug-drug interactions, patient allergies, and incorrect doses. The BESTCare 2.0 system used at the Ministry of National Guard Health Affairs (MNGHA) in the context of the Saudi Arabian setting can be regarded as an outstanding example of an integrated HIS. **[14], [6], [8]** BESTCare applies clinical rules and inference engine to compare physician entries with patient data in Electronic Medical Record (EMR). This system has been found to enhance situational awareness and also to reduce adverse drug events (ADEs). Nevertheless, the efficiency of CPOE/CDSS is frequently questioned because of the so-called alert fatigue, when clinicians start to ignore a lot of meaningless alerts and choose to ignore the potentially important communications. **[7]**

According to a study conducted at King Abdulaziz Medical City (KAMC) in Jeddah, potential drug-drug interaction (pDDI) alerts were the cause of the overridden alerts (57 percent) and dosage warnings (41 percent). This implies that there should be an improvement in the system to make sure that alerts are actionable and relevant to the clinic. Useability of the system, its availability and ease of accessing the medical history of a patient are the factors that determine the acceptance of CDSS among Saudi physicians and pharmacists.**[5], [2]**

Need of Study

Drug safety in anesthesia is one of the most dangerous aspects of patient safety in the modern healthcare. Anesthesia is associated with the use of the powerful pharmacological drugs, in complex, time-related conditions where even the slightest mistakes may lead to critical morbidity or even death. Medication errors in anesthesia cause a large percentage of adverse

perioperative events in the world, including the administration of the wrong drug, corresponding wrong dosage, and the ignorance of drug interactions. **[10]** Operating rooms and high-stress environment, the necessity to make decisions fast, and the importance of correct documentation contribute to the increase of these risks.

Electronic Health Records (EHRs), as well as Anesthesia Information Management Systems (AIMS), have become a groundbreaking technology in solving these issues. HIS may limit human error by incorporating automated documentation, real-time monitoring, and clinical decision support to redistribute communication between multidisciplinary teams and establish protocols that order medication administration in an organized manner. Barcode scanning, alerts regarding allergies, warnings about drug interactions etc features, are additional safety measures against the possible avoidable errors. Notably, HIS also produce huge data sets that facilitate the process of continuous quality improvement, audit and policy formulation. **[12], [13]** The healthcare system in Saudi Arabia has been experiencing rapid digitalization according to the Vision 2030, which focuses on patient safety, quality care, and technological innovation.

There is currently a lack of research investigating how the introduction of Health Information Systems (HIS) has improved the way anaesthetists provide safe medications for patients. In Saudi Arabia, where cultural, organisational and regulatory contexts are very different from other countries, this systematic review will combine all the available research to determine how HIS can continue to help deliver safer anaesthesia. The objective of this systematic review is therefore to review the research published in Saudi Arabia regarding the impact HIS has on improving the safety of anaesthetic medication. In collating these results, this review will report on the successes and limitations identified and will provide recommendations for future anaesthetic care and HIS development within Saudi Arabia.

Study Objective

By conducting this systematic review, we will have a comprehensive understanding of how Health Information Systems (HIS) are currently utilized in the Kingdom of Saudi Arabia, including Electronic Health Record (EHR), Anesthesia Information Management System (AIMS) to improve the safety of drugs administered in anaesthesia. Furthermore, we will examine the ability of HIS to reduce errors pertaining to drugs used during anaesthesia, e.g., wrong drug given, incorrect dose given, missed drug-drug interactions.

2. RESEARCH METHODOLOGY

Research Question

The research questions of the current study are:

Q1. In what ways do Health Information Systems, including Electronic Health Record and Anesthesia Information Management Systems, help improve medication safety while patients are receiving anesthesia in Saudi Arabian healthcare environments?

Q2. Which medications typically used for anesthesia are most commonly associated with error and reduced due to HIS in Saudi Arabia?

Q3. What kind of medication error can HIS reduce that relates to the anesthetic agents used?

Research Design

To implement a methodologically rigorous and transparent study, this paper is based on a systematic review design, which is informed by the Preferred Reporting Items on Systematic Reviews and Meta-Analyses (PRISMA) framework. The review targets published articles that investigated how Health Information Systems (HIS), such as Electronic Health Records (EHRs) and Anesthesia Information Management Systems (AIMS), can enhance medication safety in anesthesia in Saudi Arabia healthcare facilities. International databases including PubMed, Scopus, Web of Science and the Saudi Digital Library have been searched comprehensively to get both the global and the region-specific evidence. Thematic synthesis was used to determine patterns, benefits, and challenges appearing regularly, whereas methodological quality was evaluated through systematic reviews-based instruments of appraisal. Such design allows systematic and evidence-based assessment of the HIS utility in the reduction of medication errors in the anesthesia process and points to the contextual issues peculiar to Saudi Arabia.

Search Strategy

An extensive search plan was designed to find the pertinent literature on the topic of discovering the role of Health Information Systems (HIS) in enhancing the medication safety of anesthesia in Saudi Arabia. Grey literature sources including conference proceedings, Ministry of Health reports, and dissertations found in the Saudi Digital Library were also filtered in order to determine unpublished or non-indexed studies. Included articles were hand-searched to find other relevant publications in their reference lists. Search strategy was formulated to be as sensitive as possible and specific to medication safety in anesthesia so as to ensure that quantitative and qualitative evidence in Saudi Arabia was included in the search strategy to be synthesized.

Types of Studies Included

This systematic review incorporated the empirical research in Saudi Arabian healthcare settings that investigated the role of Health Information Systems (HIS) of Electronic Health Records (EHRs), Anesthesia Information Management Systems (AIMS), and other digital systems in enhancing medication safety in the course of anesthesia. The eligible studies comprised a variety of designs, such as randomized controlled trials, observational studies (cross-sectional, cohort, and case-control), qualitative research, and mixed-methods studies, as they needed to report the outcomes related to the problem of anesthesia medications safety. Systematic reviews and meta-analyses dedicated to Saudi Arabia were also included in case of the presence of the anesthesia-specific data. Included in the studies were those that specifically covered the HIS interventions (e.g., automated documentation, barcode verification, clinical decision support, error reporting systems) and the effects that such interventions have in reducing medication errors or improving patient safety.

Keywords

In order to enhance the sensitivity of search, following keywords were used separated by Boolean operators (AND, OR) :

"Health Information Systems" OR "Electronic Health Records" OR "Anesthesia Information Management Systems" OR "Clinical Decision Support" AND "Medication Safety" OR "Drug Errors" OR "Medication Errors" OR "Pharmacovigilance" AND "Anesthesia" OR "Anaesthesia" OR "Perioperative Care" OR "Operating Room" AND "Saudi Arabia" OR "Kingdom of Saudi Arabia" OR "KSA".

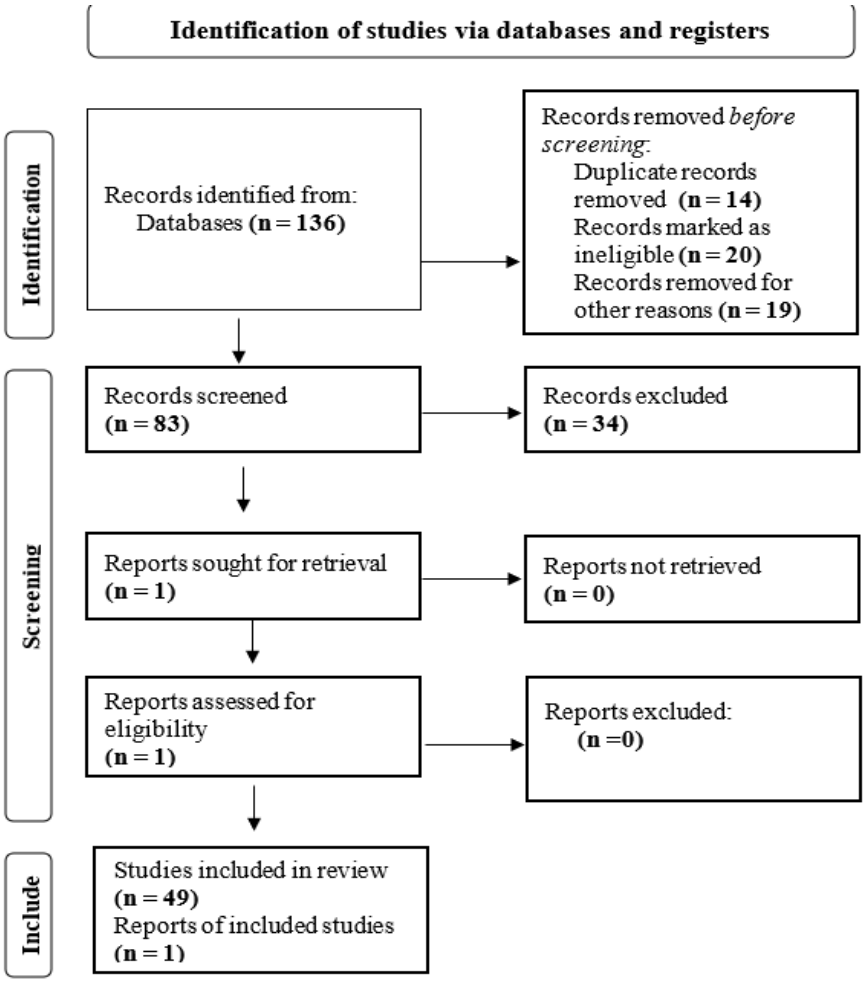
Data Management

The database searches yielding all the retrieved records were imported in a reference management software (e.g., EndNote, Mendeley, or Zotero) so that the systematic organization is performed and duplicate records are eliminated. Two reviewers independently screened titles and abstracts by comparing them with the predefined inclusion and exclusion criteria and differences were resolved by consensus or review by a third reviewer. Articles that had passed the eligibility criterion were subsequently imported into a data abstract sheet that was created in Microsoft Excel. To ensure consistency, the same coding categories were used throughout the extraction process and on a sample number of studies, pilot testing was done on the data sheet. Such a systematic data management process made the process transparent, reproducible, and accurate in the synthesis of evidence on the role of HIS in enhancing medication safety during anesthesia in Saudi Arabia.

Results

A total of 136 research studies and one report was identified, the studies were evaluated as per the availability of research articles and reports, based on the role of health information systems in improving medication safety during anesthesia in the hospitals of Saudi Arabia. Out of these identified studies, 14 were removed because of duplication of records, references and location and 20 studies were marked as ineligible, as not including the above stated concept and 19 for some other unavoidable conditions. Further 83 records were saved for screening, then in the screening process 34 records were further removed on the basis of exclusion criteria.Total studies finalized for review were 49. One report was also included in the study.

Data on the effect of Health Information Systems implementation on medication safety in the practice of anesthesia in Saudi Arabia has been proved by evidence of previous studies in Saudi Arabia. In a systematic review, Tobaiqy and MacLure (2024) emphasized that medication errors are still a major problem in Saudi hospitals, and the introduction of HIS platforms has increased the quality of error reporting, minimized duplication, and the identification of adverse drug events. Also, Alghamdi (2025) pointed out that HIS integration facilitates pharmacovigilance, enhances medication safety systems, especially with its automated documentation systems, barcode checks, and clinical decision support alerts. **[14], [15], [2]**



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The cross-sectional research on the administration of anesthetic drugs showed that the workflows supported by HIS managed to decrease the rate of wrong-drug and wrong-dose administration due to the timely verification of the information and uniformity of procedures. **[16]** In addition, HIS enhanced effective communication between the anesthesiologists, pharmacists and the nursing personnel hence reducing miscommunication during perioperative care. Although these are the advantages, a number of studies identified problems such as high implementation cost, lack of training of clinicians, and resistance to workflow changes, which may lead to poor use of HIS. In general, it can be concluded that the implementation of HIS in Saudi Arabia helps to make the anesthesia process safer, although more research should be conducted to assess the long-term results and deal with the obstacles to extensive adoption. **[17], [18], [22]**

3. DISCUSSION

Intravenous Medication Safety

Intravenous (IV) drug delivery is a risky procedure in the operating room, where it has been reported that around 38 percent of legal error instances in Saudi Arabia happen at the point of drug delivery. In response to this, the Saudi Patient Safety Centre (SPSC) published a National Medication Safety Position Paper (NMSPP) which argues in favor of the universal implementation of the so-called smart infusion pumps with the Dose-Error Reduction Software (DERS). **[9], [6], [11]** DERS enables medical establishments to establish a maximum and minimum dosage associated with each drug within a particular drug library depending on the specific area of patient care, e.g., the operating room or the ICU. The clinician is alerted through audio and visual signals when he or she tries to enter a dose either below or beyond these limits. Hard alerts stop the administration process and soft alerts are allowed to be bypassed provided they are verified by clinicians. **[19], [20]** The SPSC states that standardization of I.V. medication concentrations and reference libraries of DERS at national level require the development of programs of governance to produce them. Moreover, the center supports a gradual interoperability of smart pumps and the EHR to automate the process of data capture on administration, and consequently lower the numbers of manual documentation errors. **[27]**

Barcode Medication Administration

A swap of syringes, or vials, is one of the most frequent types of error in anesthesia, which occurs from the mistaken identification of similar-appearing ampoules or can be brought about by the necessity to administer the drugs in rapid succession during the induction phase (unlabeled syringe confusion). **[14]** In Saudi Arabia, 56.3% of those surveyed used the labeling then withdrawal method, and 43.7% used the labeling then labeling method (statistically significant as associated with an error rate of 0.036. **[21], [7]**

In order to curb these risks, point-of-care barcode technologies have been presented. One such method is the Codonics Safe Label System (SLS), which is now accessible to Saudi public hospitals on the NUPCO platform and reads drug information via barcode, verbally and visually confirms drug and concentration, and barcodes a JCI-compliant and color-coded label.**[6], [21], [22]** The use of integrated barcode medication administration (BCMA) systems further allows improving safety because the barcode of the medication and patient wristband are scanned by improving the likelihood of errors or other reasons to 0, however, in Saudi settings, the research on the policy of BCMA deviations revealed that 29 percent of medications and 20 percent of patient wristbands were not scanned as required, and the most common reasons include technological malfunctions and environmental limitations. **[13]**

Implementation of BCMA in the operating room (OR) compared to general wards is more complicated because the administration of drugs is urgent. Nevertheless, the combination of SLS and Smart Anesthesia Manager (SAM) software has indicated compliance rate of 75-98 percent of syringe labels, which is much higher than the manual technique. **[15], [16]**

Pharmacy Automation

Automation in pharmacy, which is robotic dispensing in the form of Automated Dispensing Cabinets (ADCs), has transformed the system of drug distribution in Saudi hospitals. Medication tracking and the decreased workload of the nursing and anesthesia staff in hospitals such as Almoosa Specialist Hospital (ASH) and other hospitals in the Al-Hassa region have been enhanced by ADCs. **[23], [24]**

The user satisfaction surveys in Al-Hassa hospitals state that 81.9% of healthcare practitioners are very satisfied with ADCs, which they attribute to the enhancement of accuracy (81.3) and safer job practice (79.5). **[22]** In addition, 67.4 percent of the users said that ADCs made them better at their overall productivity. Nevertheless, the systems have their flaws, with 36.8% of users mentioning that it takes more time to refill drugs to the cabinets than the conventional way, and 18.7% of the participants were worried about possible loss of data. **[26], [27]** The combination of ADCs and EMR of the institution will mean that the medications are only dispensed once a drug order has been reviewed by a pharmacist, which will establish a closed-loop system. Adjustments in specialized anesthesia practice ADCs can be set to control access to narcotics and other high-alert drugs, including biometric identifications. **[14]**

National Surveillance

The National Health Command Center (NHCC) of Saudi Arabia is one of the first steps on the way of a national-level healthcare management and safety surveillance. The NHCC offers the Ministry of Health (MOH) real-time analytics, predictions, and recommendations in the management of the capacity and safety indicators within the Kingdom. The NHCC is also involved in the field of anesthesia and surgical safety, which involves the observation of surgical waitlists and the allocation of essential resources. Through AI-based dashboards, the NHCC has managed to cut down the waiting times of planned surgery to 17 days as opposed to 36 days. [28] In the time of crisis, like the COVID-19 pandemic, the transfer of anesthetists and surgical personnel to intensive care units was coordinated by the center, and the capacity of the system was distributed where it was required the most.[15]

The NHCC model has four stages: monitor, investigate, intervene and oversee. This centralized system enables the tracking of the effectiveness of the healthcare system at various rates of clinical and system indicators. It is also useful in tracking high impact medical equipment, i.e. mechanical ventilators, etc. [16]

Human Factors

Interventions that are technological cannot exist in isolation; they should be applied by a workforce that is usually under high pressure. It is considered among the most stressful medical specialty where there is a high rate of exposure to high stakes situations on a daily basis in Saudi Arabia that has found a critically high rate of occupational burnout syndrome (OBS) to be prevalent among anesthesia technicians with 29% of them experiencing general burnout, and 41.2% experiencing high emotional exhaustion. **[27], [28]**

This burnout is caused by staff deficit, excessive workload, and lack of teamwork.42 These are the human factors that are the direct predictors of medication errors. As an example, 60.3% of Saudi anesthesia practitioners mentioned haste and heavy workload as the most common causes of drug errors, and 46 and 48 percent of those interviewed added to the list fatigue and lack of sleep and poor communication respectively. **[29], [30]** There is also the dependency between experience and error. Evidence indicates that the less experienced anesthesia clinicians make more mistakes more often (= = 0.015). **[12]** This indicates that the HIS design should especially be tailored to the needs of junior staff members by offering them clear visual

and audible alerts that offset the lack of clinical experience. **[6]**

Artificial Intelligence

It is probable that the integration of Artificial Intelligence (AI) and machine learning will characterize the next generation of HIS in the practice of anesthesia in Saudi. Attitudes of Saudi Arabian anesthesiologists towards AI have been mostly positive, and 75.23% of respondents thought that it could allow making precise decisions and 55.04% thought that it could help to minimize medical mistakes. **[28]** The use of AI-based CDSS can aid in the monitoring of the depth of anesthesia, the prediction of hemodynamic instability, and the analysis of free-text postoperative notes using Natural Language Processing (NLP) and discovering adverse events. Already, systems, such as the Smart Anesthesia Manager (SAM), are already interrogating AIMS databases in near real-time to identify problems related to clinical care and compliance, and provides the clinician with pop-up notifications. **[13], [15]**

4. CONCLUSION

The role of Health Information Systems has gained the essential place in the anesthesia safety scene in Saudi Arabia. The systematic reviews and local cohort studies evidence confirm that digital solutions, when implemented properly, can have a substantial effect on the quality of documentation, minimize errors in its administration, and increase the efficiency of work. The process of manual to electronic records at KFSHRC and MNGHA has given an effective roadmap on the advantages of AIMS and CPOE. Trending towards a single national EHR and AIMS system to promote the provision of similar safety standards and data interoperability of both public and private hospitals. Improve clinical alerts (filter out noise) and make the DERS libraries of smart pumps uniform on a national level. Require the training of all users of anesthesia-related HIS and equipment to be certified by the manufacturer, as it is one of the primary causes of non-compliance reported by the SFDA.

Future Scope of Study

Further studies regarding the role of Health Information Systems (HIS) in enhancing medication safety during the anesthesia period in Saudi Arabia should not be limited to descriptive and cross-sectional research but include longitudinal and interventional studies that quantitatively assess the long-term effects of HIS on the outcome of patients. Multicenter trials and randomized controlled trials in tertiary hospitals would have more convincing causality and generalization evidence. It is also possible to consider the incorporation of more modern developments into the sphere of HIS, including artificial intelligence, machine learning, and predictive analytics, to identify the risks in advance and optimize the process of drug administration in the anesthesia process..

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